

APPENDIX D

TREATABILITY STUDY REPORT

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TREATABILITY STUDY REPORT

**Pownal Tannery Superfund Site
Pownal, Vermont**

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1.0 INTRODUCTION

Metcalf & Eddy of Wakefield, Massachusetts (M&E) received Work Assignment (WA) No. 045-RICO-01N9 under the United States Environmental Protection Agency (EPA) Response Action Contract No. 68-W6-0042 (RAC) to complete a Remedial Investigation/Feasibility Study (RI/FS) at the Pownal Tannery Superfund Site (the Site) in North Pownal, Vermont. M&E assigned the primary responsibility for completing most of the RI/FS including the Treatability Study to TRC Environmental Corporation of Lowell, Massachusetts (TRC).

1.1 Background

The Draft Remedial Investigation Report indicated elevated levels of several contaminants in the Lagoon Area, including chromium, lead and dioxin. Note that Toxicity Characteristic Leaching Procedure (TCLP) testing of Lagoon materials indicated that samples would not be classified as hazardous waste under Resource Conservation and Recovery Act (RCRA) and two wells in the Lagoon Area contained contaminants at concentrations exceeding their respective federal Maximum Contaminant Level.

These findings are generally consistent with previous investigations performed by others including an Engineering Evaluation/Cost Analysis (EE/CA) conducted by EPA for the Site in 1998. The EE/CA included evaluation of a stabilization/solidification alternative for the Lagoon Area but due to lack of data regarding the nature and extent of contamination, removal action was not proposed for the Lagoon Area at that time. One of the recommendations in the EE/CA related to the effectiveness and implementability of the stabilization/solidification alternative was to conduct bench-scale treatability testing on the contaminated soils to optimize the ratio of bonding agents to be blended.

Now that the remedial investigation is complete and the nature and extent of contamination in the Lagoon Area is better defined, TRC determined that stabilization/solidification is still a remedial technology that needs to be evaluated and that performance data for this technology were needed to evaluate the effectiveness and implementability of this technology.

1.2 Objective

This report summarizes the Treatability Study conducted for the stabilization/solidification of contaminated lagoon soil and sludge at the Site. The primary objective of the treatability study is to evaluate the efficacy of the technology in reducing the concentrations of soluble metals, organic, and semivolatile organic compounds (SVOCs), to produce a material that is acceptable for onsite reuse and containment.

The overall purpose of this treatability study was to evaluate the effectiveness and implementability of solidification/stabilization in treating tannery wastes from the Site. The objectives of this study are listed below:

- Identify the most promising stabilization/solidification reagents for use at the Site.
- Evaluate a number of stabilization/solidification reagents.

- Quantify the effectiveness of these reagents using physical and chemical parameters.
- Develop a range of cost-effective stabilization/solidification options for optimization as part of the FS process.

Note that rendering of the waste material as non-hazardous was not an objective of this study since none of the Site wastes are classified as RCRA-Hazardous.

1.3 Site History

The Pownal Tannery site has an industrial history that extends over 200 years ago. A summary of key, relevant operational history is presented below:

- 1780: A grist mill is constructed by Richard Brown at the site.
- 1813: Richard Brown's son, Ethan Brown converted the grist mill into a wool weaving and carding plant.
- 1840: The wool weaving and carding plant is destroyed by fire.
- 1849: A woolen mill is constructed.
- 1856: The Troy and Greenfield Railroad is constructed along the Hoosic River and the site. Note that the original railroad bed crossed the Hoosic River near the Lagoon Area and originally ran on the western side of the Hoosic River through the Woods Road Disposal Area and east of the Landfill Area.
- 1863: The woolen mill is destroyed by fire.
- 1866: The Plunket and Barber Company constructed a multistory, brick, cotton textile mill on the site.
- 1920 (approximate): A second set of railroad tracks is constructed along the eastern side of the Hoosic River and the tracks on the western side are abandoned.
- 1931: The cotton mill ceases operation.
- 1936: The mill is refurbished by the Pownal Tanning Company and opens as a cow and sheep hide tanning operation. The operation consists of hide cleaning (beaming) using a variety of chemicals (pesticides, solvents), hydrochemical stabilization of the purified leather (tanning) using trivalent chromium, dyeing and lubrication of the tanned leather, followed by pasting and finishing of the leather into a variety of textures and thickness for commercial sale.
- 1940: The mill building is expanded.
- 1962: A lagoon system (two unlined lagoons) and a screen house are constructed to precipitate solids out of the wastewater prior to discharge to the Hoosic River. One of the byproducts of the hydrochemical stabilization was a stream of wastewater containing high concentrations of metals that was pumped several hundred feet to the north into these lagoons constructed next to the Hoosic River. Wastewater was collected in the lagoons and screened to collect solids, and then the water was pumped into the Hoosic River.
- 1971: Three lagoons added to system. The five lagoons occupy 22 acres.
- 1978: A clarifier building is constructed to clarify and flocculate sludge. An estimated 250,000 to 300,000 gallons per day of wastewater are discharged to the lagoons and solids from the clarifier were disposed of in Lagoons 1 and 2.
- 1980: Lagoons 1, 3A, 3B and a portion of Lagoon 4 are filled with settled sludge.

- 1983: Lagoon 1 is covered with a 1 foot layer of silt.
- 1988: The tannery closes and files for Chapter 11 bankruptcy.

1.4 Site Conditions

Lagoon Area: The RI documented the presence of sludge in Lagoons 1, 3 and 5, as well as in a limited area of Lagoon 4. The thickness of this material varied from location to location, with the thickest deposits being 4 to 9 feet in Lagoon 1, and up to 11 feet in Lagoon 3. Deposits of sludge in Lagoon 5 were less than 4 feet in thickness. The majority of sludge appeared to have been removed from Lagoon 2. Except for the southern end of Lagoon 4 (adjacent to Lagoon 3), there was no sludge in Lagoon 4.

The sludge present in Lagoon 1 generally consisted of moist organic silt including layers of gray clay and varying quantities of hair and hid fragments. The sludge in Lagoon 1 contains layers of various colors (black, blue, white, red and gray). The upper surface of this deposit was often coated with thin (<1 inch) layers of dry white powder, which may be lime that was added to the sludge to minimize leaching of metals into the ground water.

Lagoon 1: Lagoon 1 contains the thickest accumulation of sludge, but the sludge is generally buried beneath a thin layer of cover material and so the surficial soil samples do not generally contain the highest concentrations of site contaminants. Lagoon 1 generally has the highest contaminant concentrations on the entire site.

- Several VOCs were observed in Lagoon 1, but the highest concentrations were detected in the sludge. Total VOC concentrations in the sludge were generally observed to range from 50 to 200 ppm and in one sample the total VOC concentrations exceed 1 percent.
- Several SVOCs were detected in Lagoon 1, with the highest concentrations present in the sludge buried below 1 to 2 feet of cover material.
- Elevated metals concentrations were detected in the buried sludge including Chromium at concentrations typically ranging from 10,000 to 70,000 ppm and Lead from 1,000 to 2,000 ppm.
- PCBs are present surface soil and in the sludge at concentrations ranging up to 400 ppb.
- Pesticides are present in both surface and subsurface soils in Lagoon 1, but the concentrations detected in the sludge are approximately one order of magnitude higher than the concentrations detected in the surface soils.
- Dioxin TEQs exceeded 1 ppb in several samples.
- None of the samples tested for TCLP exceeded the RCRA Hazardous Waste threshold.

Lagoon 2: Lagoon 2 contains only a very small quantity of sludge. There is no significant contrast in chemical concentrations versus depth. In general, fewer site contaminants are present in Lagoon 2, and the chemical concentrations are generally lowest in Lagoon 2 soils. A summary of the laboratory test results is presented below.

- The inorganic constituents are present at concentrations that are closer to background soil conditions. Representative maximum concentrations for some metals detected include

Arsenic at 5.2 ppm, Cadmium at 11.4 ppm, Chromium at 2,690 ppm, Lead at 192 ppm, Nickel at 19.7 ppm and Cyanide at 2.5 ppm.

- All dioxin TEQs were less than 1 ppb.
- None of the samples tested for TCLP exceeded the RCRA Hazardous Waste threshold.

Lagoon 3: Lagoon 3 is the smallest of the lagoons. Samples were collected from seven borings. In previous investigations Lagoon 3 was divided into two sublagoons, 3A and 3B, though there are no present day landmarks or other features that distinguish the two sublagoons. The lagoon is now covered with gravel fill and is largely unvegetated. A summary of the laboratory test results is presented below.

- Metals are present in the greatest concentration within the sludge layer. Cadmium was not detected in surface soils, or in the underlying gravel layer, but is present in the sludge at concentrations up to 42 ppm. Chromium and Lead are present at concentrations up to two orders of magnitude greater (Chromium up to 18,000 ppm, Lead up to 565 ppm) than in surface soils or the underlying soil.
- All dioxin TEQs were less than 1 ppb.
- None of the samples tested for TCLP exceeded the RCRA Hazardous Waste threshold.

Lagoon 4: Lagoon 4 is the largest lagoon. Samples were collected from 29 borings.

- The maximum total VOC concentration is less than 200 ppb.
- Eleven SVOCs are present in Lagoon 4.
- The highest metals concentrations in Lagoon 4 are present in the surficial soils. Lead, Chromium and Cadmium are present at higher concentrations (one to two orders of magnitude greater) in the surface soils than in the subsurface soils. Thallium was detected in MW-111U during the September 2000 sampling round at a concentration of 1.3 ppb (versus the MCL of 1 ppb) and Arsenic was detected in MW-113R at a concentration of 58.4 ppb (versus the MCL of 50 ppb).
- Several SVOCs were observed at elevated concentrations.

Lagoon 5: Lagoon 5 is mostly underwater throughout the entire year. A summary of the contaminants found in Lagoon 5 is presented below:

- Two SVOCs were detected in Lagoon 5: pentachlorophenol (6,300 ppb at one location) and bis(2-ethylhexyl)phthalate (less than 800 ppb).
- Several metals are present in Lagoon 5, including Arsenic (up to 2.1 ppb), Chromium (up to 16,100 ppb), Lead (up to 624 ppb) and Mercury (up to 4.1 ppb).
- None of the samples tested for TCLP exceeded the RCRA Hazardous Waste threshold.

1.5 Overview of Stabilization/Solidification Technology

Stabilization/solidification processes are treatment technologies, which immobilize waste materials for safe disposal or reuse. These techniques are used for one or more of the following purposes:

- To reduce the solubility of the constituents contained in the waste.
- To encapsulate the waste to prevent exposure.
- To detoxify the waste by neutralization or reaction.
- To improve the physical characteristics of the treated residuals.

Stabilization processes are those which reduce constituent solubility and mobility, or detoxify the material through chemical reaction or bonding. The physical characteristics of the material being treated may or may not be changed by the stabilization process. Encapsulation processes selectively entrap the constituents in an inert matrix, which reduces the solubility and mobility of the constituents. The physical properties of the material being treated may not be changed by the encapsulation process.

Solidification is the process of adding a sufficient quantity of solidifying additives (e.g., cement) to a material to produce a solid mass which has improved structural integrity. The contaminants do not necessarily interact chemically with the additives, but instead are mechanically locked or fixed within the solidified matrix. The solidified mass can then be used onsite as construction material or disposed onsite or in an appropriate containment cell.

Stabilization processes and solidification processes have different goals. Stabilization systems attempt to reduce the solubility or chemical reactivity of a waste by changing its chemical state or by physical entrapment (microencapsulation). Solidification systems attempt to convert the waste into an easily handled solid with reduced hazards from volatilization, leaching, or spillage due to its physical properties. The two processes are discussed concurrently because they have the common purpose of containing constituents within the material matrix, as opposed to removing or destroying the constituents.

In hazardous waste disposal, an effort is usually made to have the treated waste delisted, by passing TCLP (i.e., making the waste nonhazardous). To accomplish this goal, a variety of strategies may be used to prevent contaminant leaching, including neutralization, oxidation/reduction, physical entrapment, chemical stabilization, and binding of the stabilized solid into a monolith. The development of an appropriate treatment strategy includes the following considerations:

- This waste should be treated to obtain the most inert and insoluble form chemically and economically feasible.
- Media should be added to absorb any free liquid present.
- When necessary, a binding agent should also be added.

Several generic treatment systems have been developed for waste stabilization and solidification, but not all have been employed in remedial action on uncontrolled waste sites. The volumes of waste involved at uncontrolled waste sites generally require that the least expensive systems be

used. The large quantities and varieties of wastes that are usually present also require the use of adaptable systems that are effective over a wide range of conditions. Treatment systems that generally satisfy these needs are the pozzolanic- or Portland cement-based systems. Inexpensive, absorbent materials such as clay, native soil, fly ash, or kiln dust may also be added. Under specific circumstances, it may be necessary to select other systems that offer particular advantages such as improved waste containment, compatibility with specific wastes or increased water resistance for materials to be disposed of in wet conditions (i.e., disposed below the water table). This workplan concentrates on the major stabilization/solidification systems that can be applied cost-effectively to a wide variety of wastes.

1.6 Stabilization/Solidification Technology Evaluation

Numerous proprietary and generic treatment systems have been developed for waste stabilization and solidification. Stabilization and solidification systems must be customized or developed based on specific waste characteristics, soil characteristics, site conditions and regulatory requirements. The most common systems used for waste oil contaminated soil and sludge are the pozzolanic or Portland cement based systems. Inexpensive absorbent materials such as clay, native soils, fly ash or kiln dust may also be added.

For purposes of this treatability study, materials which can be stabilized/solidified using ex-situ treatment processes will be discussed. However, this study is also applicable to in-situ processes with minor modifications.

Cement-based stabilization/solidification processes involve mixing the material to be treated with Portland cement to form a monolithic solid material. Cement-based processes are most applicable for inorganic wastes, especially those containing metals such as lead. These processes work because the high pH of cement tends to reduce the leachability of most metals by forming metal hydroxides, which in general have lower solubility's. Cement-based processes can also be used to limit the mobility of organics by encapsulating them in a solid mass, provided that the organic materials do not interfere with the hardening process.

When Portland cement is used to solidify some materials, the primary solidification reaction is the hydration of anhydrous silicates. Sulfates in the cement combine to form calcium and sulfoaluminate hydrates. These same reactions are ordinarily observed as Portland cement concrete hydrates. The cement reaction forms a hydrated calcium silicate gel matrix. The matrix bonds and solidifies the ingredients in a stable crystalline lattice by microencapsulation; the reaction also closes the pore structure of the solidified product and reduces its permeability.

Pozzolanic-based processes involve mixing the contaminated material with siliceous material such as fly ash or blast furnace slag. These materials have little or no cementitious values, but will react with alkaline materials such as lime, cement, or calcium hydroxide to form a solidified mass. Most successful experiences with pozzolanic application involve inorganic wastes and contaminants such as lead.

A recent addition to the stabilization/solidification processes is the use of phosphate based systems. In these systems, combinations of dibasic and tribasic calcium phosphates are used to

treat various metals such as lead. The phosphates can be economically used to treat low levels of soluble lead, typically in the range of 5 to 20 milligrams per liter (mg/L).

Silicates have been used in conjunction with pozzolanic materials to encapsulate various wastes. However, silicates such as sodium silicate and potassium silicate can also be used to stabilize metals such as lead. In these processes, the silicates are added to the material as liquids, and form highly insoluble metal silicates. The primary limitation to the use of the silicates is the high cost, due to the large volume of reagent generally required.

All reagents and reagent concentrations were selected based on previous experience with similar impacted soils. This includes various superfund sites and large industrial sites. Specifically, reagent selection contained three distinct classifications, including cementitious, pozzolanic, and additive reagents. The following discussions summarize the various reagent types selected.

- Cementitious: Type I Portland cement was identified for treatment of the site sludges due to its proven reliability at treating similar types of material and contaminant concentrations. Cement provides numerous benefits for treatment, including local availability, proven reliability and good chemical and physical treatment characteristics. Cement provides both chemical treatment through microencapsulation of the target contaminants, and physical improvement through macroencapsulation and the development of a treated monolith. This is critical for materials which are treated at later disposal under wet conditions (i.e., within the water table).
- Pozzolanic: Pozzolanic reagents identified for treatment included Class "C" fly ash, and cement kiln dust (CKD). These reagents, also identified as locally available, have proven to provide cost-effective treatment alternatives for treatment of contaminated sludges. Type C fly ash is produced by the burning coal, and is primarily composed of silica and low levels of metals such as calcium and iron. The primary benefits of pozzolanic reagents include local and cost-effective supplies, improved sorbing capabilities, decreased permeability, improved chemical resistance, improved waste neutralization and improved contaminant encapsulation. Full-scale treatment advantages include lower heat of hydration temperatures and improved lubrication during mixing.
- Additives: Treatment additives were selected to improve the treatment capabilities of the cementitious and pozzolanic reagents. These additives include ferric sulfate, sodium sulfate and barium sulfate. The sulfate salts was identified due to the ability to convert metal contaminants to less soluble forms.

In general, ex-situ stabilization/solidification involves mixing the waste material with the stabilization/solidification reagent and water. This process is composed of the reagent delivery system, which is designed to deliver the reagent at a specific rate, based on the weight of material to be treated. In the case of cement, and pozzolans, the reagents are normally stored in a silo, and dispensed using a screw auger.

The majority of ex-situ stabilization/solidification processes are performed using pug mill systems. The pug mill is a portable mixing unit which is designed to break the soils or materials into small particles, and mix these materials with the stabilization reagents and water. After

mixing is completed, the mixture is then discharged to a conveyor, and stockpiled for curing and testing. Pug mills come in a wide range of types, depending on the type of soil to be treated, the stabilization reagents to be used, and the expected production rates.

2.0 TREATABILITY STUDY METHODOLOGY

This section describes the methodology used for conducting the Treatability Study.

2.1 Sample Collection

Samples for the Treatability Study were obtained in September 2000 during RI field sampling activities in the Lagoon Area. One 5-gallon bucket of materials from each lagoon (two buckets from Lagoon 1) was collected and stored onsite prior to the Treatability Study.

Samples were selected for treatability testing to obtain materials from the lagoons that are representative of site contaminant concentrations and material consistency. Three samples from the five lagoons were used to assess the treatability of lagoon materials. Since the materials in Lagoons 1, 2, and 5 are similar, a single sample was used to test the materials from these lagoons. The sample selected to represent Lagoons 1, 2 and 5 was a composite sample from Lagoon 1, since the largest volume of sludge is contained in Lagoon 1 and the chemical concentrations in that lagoon are higher than those observed in Lagoons 2 or 5.

The remaining two samples for this study were taken from Lagoons 3 and 4 due to different physical and chemical characteristics. Sludge from Lagoon 3 has similar chemical characteristics to the sludge from Lagoons 1, 2, and 5 but the sludge in Lagoon 3 contains a higher proportion of clay. The material gathered from Lagoon 4 is not similar to the sludge contained in any of the other lagoons. The Lagoon 4 material is coarser grained and contains lower concentrations of contaminants.

Note that selection of these samples was completed prior to completion of the human health risk assessment that indicated acceptable risks in Lagoon 4.

2.2 Initial Sample Preparation/Characterization

The first step in the bench-scale test consisted of sample preparation, conditioning, and laboratory analysis of the lagoon soil samples from Lagoons 1, 3 and 4.

Table 2.1-1 shows the laboratory tests performed with the baseline samples. Each bucket of soil from Lagoons 1, 3 and 4 was conditioned and scalped as described in the Treatability Study Work Plan (Attachment A) to remove debris and rocks greater than 3/8-inch. The soil was then mixed to achieve a uniform sample matrix. After conditioning, an aliquot of material from each of the three lagoon samples was submitted for laboratory analysis.

Table 2.1-1: Baseline Sample Characterization Testing					
<i>Sample Location</i>	<i>Metals/ Cyanide</i>	<i>SVOCs</i>	<i>Pesticide/ PCB</i>	<i>Dioxin/ Furans</i>	<i>TCLP metals, SVOC, Pesticides</i>
Lagoon 1 Composite	X	X	X	X	X
Lagoon 3 Composite	X	X	X	X	X
Lagoon 4 Composite	X	X	X	X	X

In addition to the lagoon samples, sample blanks were also prepared at the rate of approximately one per every ten sludge samples to be cured. Blanks were prepared using standard Ottawa 20-30 sand, using the same procedures and equipment used to process the samples. These laboratory blanks are used if necessary as control samples to evaluate whether there are nonsample related physical changes that occur to samples during the bench-scale testing.

All sample handling was conducted using Level D in accordance with the TRC Health and Safety Plan for this project. Air in the breathing zone was monitored for organic vapors and hydrogen sulfide during mixing and curing.

2.3 Selection Of Stabilization/Solidification Reagents

Based on the sample characteristics, TRC selected the most suitable stabilization/solidification reagents for evaluation in this study. Table 2.3-1 presents a list of some of the various reagent systems that were initially considered. TRC blended the lagoon samples with varying proportions of the selected reagents such as fly ash (5 percent to 15 percent) and/or Portland cement (5 percent to 15 percent) and/or other reagents. During blending, sufficient water was added to facilitate mixing.

Table 2.3-1: Potential Stabilization/Solidification Reagents
CEMENTS
Portland Cement I
Portland Cement II
Portland Cement III
Cement Kiln Dust
Calcium Oxide
Hydrated Lime
ADSORPTIVE
Fly Ash Type C
Fly Ash Type F
Bottom Ash
Slag
Fullers Earth
ORGANOPHILLIC COMPOUNDS

Table 2.3-1: Potential Stabilization/Solidification Reagents
Sorbond
Claytone
Kaolin
Diatomaceous Earth
Lopat
Bond Tone
MISCELLANEOUS
Barium Sulfate
Iron Sulfate
Potassium Silicate
Sodium Sulfate
Sodium Sulfide
Soil Sorb

2.4 Phase 1 Testing

A preliminary bench-scale (Phase 1) test was performed to identify the best candidates for more detailed bench-scale testing. The preliminary bench-scale test included blending of the three representative lagoon samples with the stabilization/solidification reagent combinations as shown in Table 2.4-1. For each of the selected lagoon samples (i.e., Lagoons 1, 3 and 4), preliminary mixes were prepared and cured according to the Treatability Study Work Plan. Approximately 500 to 750 grams of lagoon material were used to prepare each preliminary bench-scale test sample. Samples were mixed in clean glass laboratory beakers. Copies of the mixing data sheets are provided in Attachment B.

Table 2.4-1: Phase I Mixtures Studied	
<i>Sample Description</i>	<i>Sample Identification</i>
Lagoon 1, 5% Type II Cement	S-1-5C
Lagoon 1, 10% Type II Cement	S-2-10-C
Lagoon 1, 15% Type II Cement	S-3-15C
Lagoon 3, 5% Type II Cement	S-6-L3-5C
Lagoon 3, 10% Type II Cement	S-7-L3-10C
Lagoon 4, 5% Type II Cement	S-8-L4-5C
Lagoon 4, 10% Type II Cement	S-9-L4-10C
Lagoon 4, 10% Type II Cement	S-9-L4-10C (Duplicate)
Lagoon 1, 5% Type II Cement, 10% Fly ash	S-10-5C-10F
Lagoon 1, 5% Type II Cement, 20% Fly ash	S-11-5C-20FA
Lagoon 1, 5% Type II Cement, 20% Fly ash, Ferric Sulfate	S-12-5C-20FA-05 FESO4

Samples were cured for seven days. After seven days of curing, ten samples were selected for laboratory (chemical) analysis as indicated in Table 2.4-2. Samples were selected based on a minimum threshold unconfirmed compressive strength criteria of 50 pounds per square inch, as well as other visual and physical characteristics.

Table 2.4-2: Phase I Sample Characterization Testing			
<i>Sample Description</i>	<i>Sample Identification</i>	<i>TCLP Metals</i>	<i>TCLP SVOCs</i>
Lagoon 1, 5% Type II Cement	S-1-5C	X	X
Lagoon 1, 10% Type II Cement	S-2-10-C	X	X
Lagoon 1, 15% Type II Cement	S-3-15C	X	X
Lagoon 3, 5% Type II Cement	S-6-L3-5C	X	X
Lagoon 3, 10% Type II Cement	S-7-L3-10C	X	X
Lagoon 4, 5% Type II Cement	S-8-L4-5C	X	X
Lagoon 4, 10% Type II Cement	S-9-L4-10C	X	X
Lagoon 4, 10% Type II Cement	S-9-L4-10C (Duplicate)	X	X
Lagoon 1, 5% Type II Cement, 10% Fly ash	S-10-5C-10F	X	X
Lagoon 1, 5% Type II Cement, 20% Fly ash	S-11-5C-20FA	X	X
Lagoon 1, 5% Type II Cement, 20% Fly ash, Ferric Sulfate	S-12-5C-20FA-05 FESO4	X	X

2.5 Phase 2 Testing

2.5.1 Phase 2 Reagent Mixture Selection

Based on the results of the Phase 1 testing, a number of samples were selected for further study. Table 2.5-1 provides a list of the reagent mixtures selected for further evaluation. These mixtures were selected based on their performance in Phase I, based on their compressive strength, mixing characteristics, and estimated reagent costs (i.e., volume of materials used).

2.5.2 Phase 2 Mixture Preparation

The Phase II soils were treated using the reagent system and ratios indicated in Table 2.5-1 using a laboratory scale pug-mill. Approximately 5 to 7 pounds of soil was treated using each reagent mixture.

The treated materials were compacted into 2 inch by 4 inch cylinders and allowed to cure for 28 days under ambient conditions. During this time, data was collected on the hardness, and volumetric expansion, pH, temperature, visual characteristics, freeze/thaw and wet/dry testing.

After 28 days curing samples were sent for laboratory analysis for the parameters listed in Table 2.5-2.

Freeze/thaw durability testing was performed using specimens measuring 2.0 inches in diameter and 4.0 inches in height. A total of two specimens were tested for each mixture. One of the specimens was the test specimen, and the other specimen was set up as a control specimen for the purposes of comparing the effects of the freezing and thawing cycles.

Table 2.5-1: Phase II Mixtures Studied

<i>Sample Description</i>	<i>Sample Identification</i>
Lagoon 1, 5% Type II Cement	S-1-5C
Lagoon 3, 5% Type II Cement	S-6-L3-5C
Lagoon 1, 5% Type II Cement, 10% Fly ash	S-10-5C-10FA
Lagoon 1, 5% Type II Cement, 20% Fly ash	S-11-5C-20FA
Lagoon 1, 5% Type II Cement, 20% Fly ash, Ferric Sulfate	S-15-5C-10FA-05 FESO4

Table 2.5-2: Phase II Sample Characterization Testing

<i>Sample Description</i>	<i>Sample Identification</i>	<i>TCLP Metals</i>	<i>TCLP SVOCs</i>
Lagoon 1, 5% Type II Cement	S-1-5C	X	X
Lagoon 3, 5% Type II Cement	S-6-L3-5C	X	X
Lagoon 1, 5% Type II Cement, 10% Fly ash	S-10-5C-10FA	X	X
Lagoon 1, 5% Type II Cement, 20% Fly ash	S-11-5C-20FA	X	X
Lagoon 1, 5% Type II Cement, 20% Fly ash, Ferric Sulfate	S-15-5C-10FA-05 FESO4	X	X

Freeze/thaw test specimens are subjected to repeated cycles of freezing and thawing. During the freeze cycle, the test specimen is saturated in deionized for 24 hours, drained and placed in a beaker and stored in a freezer maintained at -15°C . In the thaw cycle, the specimen in the beaker is covered with deionized water and stored in a room maintained at room temperature. Each cycle lasts approximately 24 hours. The control specimen is subjected to similar cycles as the test specimen, with the exception that, instead of the freeze cycle, the control specimen is stored in a closed container maintained at room temperature and near 100 percent humidity.

The freeze/thaw durability specimen is evaluated for its ability to maintain its physical characteristics after undergoing the six cycles of freezing and thawing. As specified by ASTM D4842, if the freeze/thaw test specimen exhibits less than 30 percent cumulative mass loss after the six cycles, it is judged to pass the freeze/thaw durability testing. However, if the specimen exceeds 30 percent cumulative mass loss during the testing program, it is judged to fail. The methodology for ASTM D4842/4843 states that the test methods are intended for evaluation of monolithic specimens. Stabilization generally produces treated materials that are semimonolithic in nature, and therefore ASTM D4842/4843 are the most appropriate methods

for evaluating the durability of monolithic materials, although the Pownal materials are not monolithic, they performed adequately in the testing.

Wet/dry testing is performed using similar protocols as outlined above for freeze/thaw testing, with the exception that, instead of placing the test specimen in a freezer, the test specimen is placed in an oven maintained at a temperature of 70° C. All other protocols are similar between the two test methods.

After the 28-day cure, the volumetric expansion due to addition of the treatment reagents was determined for each mixture. This was measured by compacting a preweighed aliquot of sludge into a cylindrical sample mold. The volume of the as-received sludge was measured and recorded. The sludge was then removed from the mold, and treated in accordance with the protocols outlined above. Upon completion of the treatment process, the material was again compacted into the same type of sample mold and allowed to cure for a period of 28 days. After completion of the 28 day cure, the volume of the treated material was measured and recorded.

3.0 STABILIZATION/SOLIDIFICATION TREATABILITY STUDY RESULTS

This section presents the results of the Treatability Study testing. Attachment C contains the Laboratory Report for all laboratory test results presented in this section.

3.1 Preliminary Testing Results

Prior to mixing the samples with the bonding agents, baseline laboratory analysis was completed to establish that the samples used for the testing were representative of the contaminant concentrations observed during the RI and for comparison to analysis of the stabilized samples. Table 3.1-1 shows the results this baseline analysis. The results indicate that the composite lagoon samples are representative of the material sampled during the RI. Most contaminant concentrations are $\pm 25\%$ of those observed during the RI.

3.2 Phase 1 Results

The preliminary mixtures were cured for 7 days. After curing for 7 days, the mixtures were analyzed as follows:

- Unconfined compressive strength
- Temperature
- Visual characteristics
- pH
- TCLP Metals
- TCLP SVOC's
- TCLP Pesticides

Tables 3.2-1 and 3.2-2 present the results of these analyses.

A description of each test and the corresponding results is provided below.

During mixture preparation, volatile organic emissions were monitored using a PID meter. The volatile organic emissions monitoring was performed by placing the PID meter on a rigid stand with the probe directly over the blending chamber. PID readings were recorded at various times throughout the treatment process, including before treatment, during treatment and immediately after completion of the treatment process. The temperature increase in the materials due to addition and hydration of the treatment reagents was determined using a digital temperature probe. Temperature monitoring was performed at the same intervals used for organic emissions monitoring, including before treatment, during treatment and immediately after completion of the treatment process.

Table 3.1-1: Untreated Sample Results**Pownal Tannery Superfund Site**

CONSTITUENT	LAGOON NO. 1	LAGOON NO. 3	LAGOON NO. 4
TCLP Metals (µg/L)			
Arsenic	3.0U	3.0U	7.4
Barium	587	403	396
Cadmium	3.4U	0.3U	17.5
Chromium	1,230	1,700	6,420
Lead	3.0U	3.0U	20.4
Mercury	0.70U	0.70U	3.6
Selenium	12.9	15.3	25.7
Silver	3.9	4.0	8.0
TCLP SVOCs (µg/L)			
2-Methylphenol	33U	33U	33U
4-Methylphenol	33U	33U	33U
Hexachloroethane	33U	33U	33U
Nitrobenzene	33U	33U	33U
Hexachlorobutadiene	33U	33U	33U
2,4,6-Trichlorophenol	33U	33U	33U
2,4,5-Trichlorophenol	9J	67U	67U
2,4-Dinitrotoluene	33U	33U	33U
Hexachlorobenzene	33U	33U	33U
Pentachlorophenol	27J	67U	67U
Pyridine	33U	33U	33U
4,4'-DDE	1.5JJ	4.6U	4.3U
4,4'-DDD	3.5	4.6U	4.3U
alpha-chlordane	4.2J	2.4U	2.2U
gamma-chlordane	3.4J	2.4U	2.2U
Metals (mg/kg)			
Aluminum	9,140J	9,380	10,700
Antimony	2.8	3.3J	1.5J
Arsenic	7.7	5.7	6.6
Barium	117	105	80.5
Beryllium	0.41J	0.40J	0.41J
Cadmium	13.7	11.0	3.8
Calcium	37,700	46,900	23,200
Chromium	3,760	4,330	1,880
Cobalt	10.7J	9.7J	10.4J
Copper	36.3	34.2	30.4
Iron	22,400	21,300	22,600
Lead	170	186	84.9
Magnesium	4,900	5,110	5,440
Manganese	736	1,160	924
Mercury	5.2	7.0	1.5
Nickel	19.8	19.3	20.5
Potassium	809J	796J	822J

Table 3.1-1: Untreated Sample Results**Pownal Tannery Superfund Site**

CONSTITUENT	LAGOON NO. 1	LAGOON NO. 3	LAGOON NO. 4
Selenium	1.3U	1.3U	1.1U
Silver	0.14U	0.14J	0.12U
Sodium	490J	1,140J	293J
Thallium	3.0	3.0	2.6
Vanadium	12.4J	13.3J	13.0
Zinc	92.7	78.8	70.6
Cyanide	0.15U	0.20J	0.15J
PCBs	U	U	U
Dioxins/Furans (ng/kg)			
Total TCDDs	161	231	138
Total PeCDDs	412	350	221
Total HxCDDs	3,200	1,670	815
Total HpCDDs	58,600	20,200	9,020
Total TCDFs	78.6	52.2	21.8
Total PeCDFs	220	125	61.1
Total HxCDFs	1,660	733	415
Total HpCDFs	5,410	3,560	1,900
Total PCDD/Fs			
TEQ (ND=0)	543	278	151.7
TEQ (ND=1/2)	543	278	151.7
TEQ w/EMPC (ND=0)	543	278	151.7
TEQ w/EMPC (ND=1/2)	543	278	151.7
TCLP Pesticides	U	U	U

Table 3.2-1: Summary Of Phase I Mixes And Mixing Data

SAMPLE NO.	BASE MATERIAL TYPE	REAGENT TYPE	REAGENT ADDITION (%)	TEMPERATURE 0° C			VISUAL CHARACTERIZATION			pH			UNCONFINED COMPRESSIVE STRENGTH (tons/sf)		
				Day 1	Day 3	Day 7	Day 1	Day 3	Day 7	Day 1	Day 3	Day 7	Day 1	Day 3	Day 7
S-1-5C	Lagoon No. 1 Soil	Type II Cement	5	120	Amb	Amb	U	U	U	11.65	11.45	--	>5	>5	>5
S-2-10C	Lagoon No. 1 Soil	Type II Cement	10	117	Amb	Amb	U	U	U	11.92	11.70	--	>5	>5	>5
S-3-15C	Lagoon No. 1 Soil	Type II Cement	15	124	Amb	Amb	U	U	U	11.75	11.60	--	>5	>5	>5
S-4-25FA	Lagoon No. 1 Soil	"Hondo" Fly Ash	25	118	Amb	Amb	U	U	U	11.45	11.52	--	2.75	4.50	>5
S-5-10C-10F	Lagoon No. 1 Soil	Type II Cement/Fly Ash C	10/10	114	Amb	Amb	U	U	U	11.60	11.41	--	2.0	>5.0	>5.0
S-6-L3-5C	Lagoon No. 3 Soil	Type II Cement	5	118	Amb	Amb	U	U	U	11.72	11.57	--	>5.0	>5.0	>5.0
S-7-L3-10C	Lagoon No. 3 Soil	Type II Cement	10	120	Amb	Amb	U	U	U	11.25	11.40	--	>5.0	>5.0	>5.0
S-8-L4-5C	Lagoon No. 4 Soil	Type II Cement	5	111	Amb	Amb	U	U	U	11.29	11.35	--	>5.0	>5.0	>5.0
S-9-L4-10C	Lagoon No. 4 Soil	Type II Cement	10	110	Amb	Amb	U	U	U	11.42	11.37	--	>5.0	>5.0	>5.0
S-10-5C-10FA	Lagoon No. 1 Soil	Type II Cement/Fly Ash C	5/10	114	Amb	Amb	U	U	U	11.66	11.47	--	2.75	>5.0	>5.0
S-11-5C-20FA	Lagoon No. 1 Soil	Type II Cement/Fly Ash C	5/20	120	Amb	Amb	U	U	U	11.46	11.35	--	3.25	>5.0	>5.0
S-12-5C-20FA-05FES04	Lagoon No. 1 Soil	Type II Cement/Fly Ash C/Ferric Sulfate	5/20/0.5	116	Amb	Amb	U	U	U	11.70	11.62	--	3.0	>5.0	>5.0
S-13-5C-10F-INaSO4	Lagoon No. 1 Soil	Type II Cement/Fly Ash C/Sodium Sulfate	5/10/1.0	114	Amb	Amb	U	U	U	11.71	11.57	--	1.5	4.5	>5.0
S-14-5C-20F-05BaSO4	Lagoon No. 1 Soil	Type II Cement/Fly Ash C/Barium Sulfate	5/20/0.5	114	Amb	Amb	U	U	U	11.39	11.43	--	4.0	>5.0	>5.0

Amb = Ambient
Acceptable visual characteristics.

Table 3.2-2: Phase I (Treated) Sample Results													
CONSTITUENT	HAZARDOUS WASTE CRITERIA (ug/L)	MAXIMUM CONTAMINANT LEVEL (MCL) (ug/L)	S-1-5C	S-2-10C	S-3-15C	S-6-L3-5C	S-7-L3-10C	S-8-L4-5C	S-9-L4-10C	S-10-5C-10F	S-10-5C-10F	S-11-5C-20FA	S-12-5C-20FA -05 FES04
TCLP Metals													
Arsenic	5,000	50	30U	30.0U	30.0U	30.0U	30.0U	30.0U	30.0U	30.0U	30.0U	30.0U	30.0U
Barium	100,000	2,000	312J	490J	805J	302J	325J	321J	343	516J	516J	1,250J	981J
Cadmium	1,000	5	3.0U	3.0U	3.0U	3.0U	3.0U	3.0U	3.0U	3.0U	3.0U	3.0U	3.0U
Chromium	5,000	100	1,030	876	459	342	942	388	736	635	635	276	218
Lead	5,000	15J	20U	20.0U	20.0U	20.0U	20.0U	20.0U	20.0U	20.1U	20.1U	28.6J	20.0U
Mercury	200	2	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U
Selenium	1,000	50	40U	40.0U	40.0U	40.0U	40.0U	40.0U	40.0U	40.0U	40.0U	40.0U	40.0U
Silver	5,000	--	20U	20.0U	20.0U	20.0U	20.0U	20.0U	20.0U	20.0U	20.0U	20.0U	20.0U
TCLP SVOCs													
2-Methylphenol	--	--	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U
4-Methylphenol	--	--	33U	4J	33U	3J	4J	33U	33U	33U	33U	33U	33U
Hexachlorethane	--	--	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U
Nitrobenzene	--	--	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U
Hexachlorobutadiene	--	--	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U
2,4,6-Trichlorophenol	--	--	6J	4J	33U	4J	33U	33U	33U	33U	33U	33U	33U
2,4,5-Trichlorophenol	--	--	51J	38J	23J	3J	67U	6J	6J	22J	22J	16J	14J
2,4-Dinitrotoluene	--	--	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U
Hexachlorobenzene	--	--	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U
Pentachlorophenol	--	--	32J	7J	67U	67U	67U	4J	67U	67U	67U	67U	67U
Pyridine	--	--	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U	33U

02136-0220-01N98(5/8/01/Ks)

Very low organic emissions were detected for all of the mixtures developed. Generally, volatilization rates were slightly elevated during mixing, and then decreased upon completion of the blending process. Slightly higher volatilization rates were observed for treatment of Lagoon 1 than those obtained during treatment of the Lagoon 3 or 4. However, all of the emissions were well below any anticipated regulatory limits or worker safety concerns.

Temperature monitoring revealed temperature increases for all mixtures developed. For all mixtures, temperatures increased throughout the treatment process and into the curing process. The slight temperature increase is attributed to the hydration of the cementitious reagents, and was anticipated as a result of the treatment process.

The pH monitoring indicated no significant changes during the curing process.

After bonding the treated materials were compacted into cylindrical molds measuring 2 inches in diameter and 4 inches in height. The treated mixtures were allowed to cure for 7 days in a humid environment and at a temperature maintained between 18 and 24 °C (64 to 75 °F). Throughout the treatment, monitoring and compaction process, visual observations were performed of each treated samples.

During the 7 day curing period, penetrometer analyses were conducted on each of the treated materials at cure times of 4 hours, and 1, 3 and 7 days. These analyses served as screening tests to estimate the setting and strength properties of the treated materials. Testing was conducted using a Brainard-Kilman S-170 Pocket penetrometer, calibrated by the manufacturer in increments of 0.25 tons per square foot (tons/ft²) with a maximum of 5.0 ton/ft² (76 psi). The results of the penetrometer testing are presented in Table 3.2-1. Review of these data indicate that all mixtures achieved penetrometer strength values of greater than 5.0 ton/ft² after 7 days of curing.

3.3 Phase 2 Results

Table 3.1-1 presents the laboratory results of the analysis of the Phase 2 materials after solidification. The results indicate the following.

- TCLP metals:
 - Chromium levels were above MCLs, but below hazardous waste criteria.
 - Lead levels were above MCLs but below hazardous waste criteria.
- TCLP SVOC levels were below detection limits.
- TCLP Pesticides levels were below detection limits.

As part of the Phase 2 testing, in addition to the analytical analysis, the samples were subjected to several physical tests. These tests included the following.

- Unconfined Compression Strength
- Volume Expansion
- Freeze Thaw Durability Testing (6 cycles)
- Wet/Dry durability (6 cycles)

- pH
- Temperature

Tables 3.3-3 and 3.3-4 present the results of freeze/thaw and wet/dry durability testing. Also included are the maximum volumetric change and cumulative mass loss for each test and control specimen. The results presented in Table 3.3-3 for the freeze/thaw durability testing and Table 3.4-2 for the wet/dry durability testing indicate that the candidate mixtures selected for the additional testing performed as well as anticipated. The visual observations indicate the mixtures produced a soil crete like material. The mixtures also achieved a confined penetrometer strength in excess of $>5.0 \text{ ton/ft}^2$ (76 lb/in^2). TCLP evaluations indicate that the chemical leachability remained at acceptable levels. These data indicate that the stabilization process was effective at improving the geotechnical properties of the raw sludge while minimizing the metal leachability.

The durability results show that the site sludge and soils mixed with 5 percent cement and enhanced with 10 percent fly ash "C" will effectively stabilize the raw materials to achieve adequate durability for the materials.

The results of unconfined compressive strength testing are summarized in Table 3.4-3. The data presented in Table 3.4-3 indicate that treatment of the material resulted in strength values after 28 days of curing that are sufficient to support a cap or recreational fields as desired by the Town of Pownal.

Table 3.4-3 also presents temperature and pH data for the treatability samples. No anomalous readings were noted in any of the samples.

Table 3.3-1: Phase II (Treated) Sample Results

CONSTITUENT	Hazardous Waste Criteria (ug/L)	Maximum Contaminant Level (ug/L)	S-1-5C	S-10-5C-10FA	S-11-5C-20FA	S-15-5C-10FA-05FES04	S-6-L3-5C
TCLP METALS							
Arsenic	5,000	50	27.1U	16.3U	12.2U	10.5U	35.0U
Barium	100,000	2,000	918U	713U	217U	599U	768U
Cadmium	1,000	5	8.3U	2.0U	0.30U	1.4U	4.4U
Chromium	5,000	100	3,950	749	69.4	214	5,720
Lead	5,000	15J	29.3	11.9	2.6	7.6U	38.7
Mercury	2,000	2	1.0J	1.0J	1.0J	1.0J	1.0J
Selenium	1,000	50	8.0U	15.2U	28.2	12.6U	6.2U
Silver	5,000	--	7.8U	5.2U	4.1U	4.6U	4.9U
TCLP SVOC's	--	--	J	J	J	J	J
2-Methylphenol			33J	33J	33J	33J	33J
4-Methylphenol			33J	33J	33J	33J	33J
Hxachloroethane			33J	33J	33J	33J	33J
Nitrobenzene			33J	33J	33J	33J	33J
Hexachlorobutadiene			33J	33J	33J	33J	33J
2,4,6-Trichlorophenol			33J	33J	33J	33J	33J
2,4,5-Trichlorophenol			3J	4J	4J	5J	67J
2,4-Dinitrotoluene			33J	33J	33J	33J	33J
Hexachlorobenzene			33J	33J	33J	33J	33J

Table 3.3-1: Phase II (Treated) Sample Results

CONSTITUENT	Hazardous Waste Criteria (ug/L)	Maximum Contaminant Level (ug/L)	S-1-5C	S-10-5C-10FA	S-11-5C-20FA	S-15-5C-10FA-05FES04	S-6-L3-5C
Pentachlorophenol			67J	8J	4J	13J	67J
Pyridine			33J	33J	33J	33J	33J
Pesticides	--	--	J	J	J	J	J

Table 3.3-2: Phase II Mixes And Mixing Data																	
SAMPLE NO.	BASE MATERIAL TYPE	REAGENT TYPE	REAGENT ADDITION (%)	TEMPERATURE 0° C			VISUAL CHARACTERIZATION			pH			UNCONFINED COMPRESSIVE STRENGTH			FREEZE THAW TESTING	WET/DRY TESTING
				Day 7	Day 14	Day 28	Day 7	Day 14	Day 28	Day 7	Day 14	Day 28	Day 7	Day 14	Day 28		
S-1-5C	Lagoon No. 1 Soil	Type II Cement	5	115	Amb	Amb	(1)	(1)	(1)	11.70	11.55	--	>5.0	>5.0	>5.0	Pass	Pass
S-10-5C-10FA	Lagoon No. 1 Soil	Type II Cement/ Fly Ash C	5/10	122	Amb	Amb	(1)	(1)	(1)	11.81	11.60	--	2.0	>5.0	>5.0	Pass	Pass
S-11-5C-20FA	Lagoon No. 1 Soil	Type II Cement/ Fly Ash C	5/20	115	Amb	Amb	(1)	(1)	(1)	11.47	11.49	--	1.5	>5.0	>5.0	Pass	Pass
S-6-L3-5C	Lagoon No. 3 Soil	Type II Cement	5	124	Amb	Amb	(1)	(1)	(1)	11.82	11.43	--	>5.0	>5.0	>5.0	Pass	Pass
S-15-5C-10FA-05FeSOy	Lagoon No. 1 Soil	Type II Cement/ Fly Ash C/Ferrie Sulfate	5/10/0.5	118	Amb	Amb	(1)	(1)	(1)	11.98	11.66	--	0.5	4.5	>5.0	Pass	Pass

Amb = Ambient
(1) Acceptable visual characteristics.

4.0 CONCLUSIONS

This Treatability Study demonstrated that solidification/stabilization of the Pownal Lagoon materials and soils can achieve the treatment objectives. This study demonstrated the following.

- Solidification/stabilization can maintain the leachability of the COCs to below hazardous waste criteria and to below MCL levels as measured by TCLP extraction.
- Solidification/stabilization treatment produces a monolithic material that:
 - Will provide sufficient strength to allow handling, placement and capping.
 - Will provide sufficient strength material to support a cap.
 - Will provide a material with sufficient strength and longevity as demonstrated by the freeze/thaw and wet/dry testing.
- Solidification/Stabilization
- Eliminates the presence of free liquids after treatment.
- Freeze thaw and wet/dry data indicates that the materials have sufficient strength to allow disposal in wet conditions.